MDDC - 953

UNITED STATES ATOMIC ENERGY COMMISSION

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This document consists of 2 pages.
Date of Manuscript: May 1, 1947
Date Declassified: May 7, 1947

Technical Information Division, Oak Ridge Directed Operations

Oak Ridge, Tennessee

A SIMPLE DEMONSTRATION OF RESONANCE SCATTERING*

By Alexander Langsdorf, Jr. and Wayne Arnold

The Breit-Wigner theory predicts that at a neutron absorption resonance there should also be a large scattering cross section and that the ratio of the peak cross sections at resonance should be in the ratio of the widths Γ_n and Γ_γ. For the well-known resonances, such as those in gold, silver, and indium, the neutron width Γ_n is much smaller than the gamma width, Γ_γ, so that the scattering intensity expected to be found is quite weak. However, we have demonstrated the existence of the scattering resonance, both by activation of foils and by use of a BF_3 filled ion chamber detector, using neutrons scattered from a beam brought out of the Argonne heavy-water pile. The results shown in the table of data were obtained in the fall of 1944. They demonstrate that in the three elements tested, the scattering resonance has a magnitude of at least 100 times 10^{-24} cm^2/atom, or over 10 times the normal scattering cross sections found for these elements.

Data on the values of Γ_γ and Γ_n obtained by modulated cyclotron velocity spectrometers indicate that Γ_γ may be expected to be 10 to 100 times Γ_n, which gives expected peak values of σ_{scat}, even larger than those found here.

Unpublished work similar to that here reported has been carried out since this work was done. In May 1945, R. B. Sawyer, J. Blair, and E. O. Wollan issued a report (CP-3498) on a measurement and analysis of the scattering cross section at the 1.44-ev indium resonance, which indicated a peak scattering cross section of about 1100 x 10^{-24} cm^2/atom, and in January 1947 E. Fermi and L. Marshall found 1000 x 10^{-24} cm^2/atom for this resonance and about the same for the 5.2-ev silver resonance (CP-3750).

In spite of the strength of the beam from the piles, all the above work suffered from fairly high background intensities from neutrons scattered by air or which leaked into the detector in spite of attempts to shield it. This, combined with the great loss in intensity due to the small solid angle of the scattered neutrons picked up by the detectors, leads to great inaccuracy in the results.

Further improvement in technique is necessary and valuable, because if sufficient accuracy can be attained in determining the resonance energy, Γ_n and Γ_γ, then the spin of the compound nucleus should be evaluable with certainty.

That is, given a knowledge of

$$\sigma_{s0}/\sigma_{a0} = \Gamma n/\Gamma\gamma = \rho \text{ , then}$$

$$\sigma_{a0} = \pi\lambda\!\!\!^{-2}\left[1 \pm 1/(2I+1)\right] \rho/(1+\rho)^2$$

and the undetermined sign of the spin term can be evaluated, if $\pi\lambda\!\!\!^{-2}$, and σ_{a0} are known well, along with ρ determined from the scattering experiments.

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*Paper presented at meeting of American Physical Society, Washington D. C., May 1–3, 1947

In the paper next to be prepared by Fred Seidl, we are reporting work recently resumed in this field following the discovery by Goldhaber of the remarkably strong resonance scattering by Mn. The same difficulties in obtaining accuracy enough to define the sign of the spin term persist in this other type of resonance.

It is interesting to note that in the absorption resonances σ_{a0} only approaches its maximum possible value when $\Gamma_n \simeq \Gamma_\gamma$, at $\Gamma_n = \Gamma_\gamma, \sigma_{a0} = \pi \lambda\!\!\!^{-2} [1 \pm 1/(2I + 1)] \cdot \frac{1}{4}$, while the scattering approaches closely its maximum value of $\pi \lambda\!\!\!^{-2}[1 \pm 1/(2I + 1)]$ whenever $\Gamma_n \gg \Gamma_\gamma$. This circumstance makes the probability of finding extremely strong absorption resonances less likely that that of finding extremely strong scattering resonances. Now that one such scattering resonance is known in manganese, it will be of interest to find how common such scattering resonances may be. They may turn out to be of fairly frequent occurrence.

Table 1. Transmission of absorbers for scattered radiation detected by BF_3 counter.

Absorber (g/cm²)	Scatterer (g/cm²)	
	Ag 0.042	C 0.079
0.13 Ag	0.74 ± 0.07	0.976 ± 0.015
1.04 Ag	0.61 ± 0.07	0.84 ± 0.02
0.1 B	0.71 ± 0.10	0.64 ± 0.03
0.42 In	0.79 ± 0.09	0.72 ± 0.03
	Scatterer (g/cm²)	
	Au 0.26	C 0.079
0.26 Au	0.82 ± 0.04	0.95 ± 0.03
	Scatterer (g/cm²)	
	In 0.023	C 0.079
0.42 In	0.45 ± 0.14	0.72 ± 0.03

Table 2. Relative counts from detectors irradiated by scattered neutrons in right angle geometry.

Detector (g/cm²)	Scatterer (g/cm²)			Air and "leakage"
	In 0.014	Ag 0.031	C 0.12	
0.097 In	320	86	(1000)	320
0.024 Ag	158	830	(1000)	360